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## THE STRUCTURES, ORIGIN, AND NOMENCLATURE OF THE ACID VOLCANIC ROCKS OF SOUTH MOUNTAIN.

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THE identification of acid and basic volcanic rocks in the South Mountain, Pennsylvania, has already been announced.<sup>1</sup> This announcement has been further substantiated by detailed petrographical study which it will be the purpose of a later communication to discuss. The present discussion of these rocks will be limited to the acid volcanics, and its object will be; a) to show that the acid volcanics were originally identical with their recent volcanic analogues; b) to further show that their present differences are due to changes subsequent to solidification, chief among which has been devitrification; and c) to propose a name for them that shall express these facts. The structures, which will be described in the course of the paper, will be considered a sufficient guarantee of the igneous origin of the rocks which possess them, without further proof on that point.

Three distinct rock types have been recognized in the South Mountain. (1) A silicious sedimentary formation, represented by a quartzose conglomerate, a sandstone, and a compact quartzite. This is rarely accompanied by an interbedded argillaceous slate. The age of these sediments has been recently determined as lower-Cambrian by Mr. Walcott<sup>2</sup> from the discovery of fossils in the interbedded slates. Underlying these Cambrian sediments, but exposed by erosion for many square miles (150-175), are two types of volcanic rocks, distinctly different in chemical composition but affected by like conditions of con-

<sup>1</sup> G. H. WILLIAMS: The Volcanic Rocks of South Mountain, in Pennsylvania and Maryland. *Am. Jour. Sc.*, XLIV., Dec., 1892, pp. 482-496, pl. I. *The Scientific American*, Jan. 14, 1893.

<sup>2</sup> C. D. WALCOTT: Notes on the Cambrian Rocks of Pennsylvania and Maryland from the Susquehanna to the Potomac. *Am. Jour. Sc.*, Vol. XLIV., Dec. 1892, p. 481.

solidation and subsequent alterations. (2) In the northern part of the range a brilliantly colored acid volcanic rock predominates. It is porphyritic or non-porphyritic, amygdaloidal or compact. It is accompanied by pyroclastics and breccias. It is sometimes sheared into a fissile slate or sericite schist. (3) Toward the south and extending into Maryland a dark green basic volcanic rock predominates. This is also amygdaloidal or compact, accompanied by pyroclastics or breccias, and usually rendered schistose by pressure.

*The acid volcanics.*—While some of the acid volcanics are typical quartz-porphyrries, others possess a groundmass which, although holocrystalline, contain the evidence of a distinctly different original character. It is this important portion of the acid flow, which will be more particularly treated in what follows. Certain conspicuous structures of the groundmass contain the history of the rock and merit a detailed description.

*Fluidal structure.*—The fluidal structure, which is a familiar one to all students of rhyolitic lavas, is a marked feature of these pre-Cambrian volcanics. Delicate lines of flow are brought out in great detail by weathering or are painted in brilliant colors in the material washed by the mountain brooks. The microscope shows globulites of magnetite, and hematite, and indefinite opaque microlites following sinuous lines of flow, twisting around the phenocrysts and imparting to them the appearance of eyes.

*Micropoikilitic structure.*<sup>1</sup>—This name has been given to a structure which is almost universally present in the acid and more rarely in the basic volcanics of the South Mountain. It consists in the presence in the groundmass of irregular quartz areas enclosing microlites of lath-shaped feldspars or other minerals with independent optical orientation. This structure between crossed nicols gives a pronounced mottled or patchy appearance to the groundmass, an appearance which has not infrequently been noted in volcanics of all ages. It has been variously described, usually without being named, in quartz-

<sup>1</sup>G. H. WILLIAMS: On the Use of the Terms Poikilitic and Micropoikilitic in Petrography. Jour. of Geol., Vol. I., No. 2, February-March, 1893, pp. 176-179.

porphyries, felsites, porphrites, peridotites, and rhyolites by numerous writers.<sup>1</sup> This structure was also found in the pre-Cambrian felsite of Georgia,<sup>2</sup> and in felsites of the same age in the neighborhood of Boston,<sup>3</sup> and from Marblehead Neck, Mass.

While the term micropoikilitic is not restricted to a quartz-feldspar intergrowth, in most of the occurrences described these have been the component minerals. In the rocks under discussion the feldspathic material is often so abundant as not to permit of the determination of the mineral character of the host. In such cases, however, a clue to the nature of the cementing material is found in its optical continuity with the porphyritical quartz. The feldspar phenocrysts, on the other hand, do not

<sup>1</sup>R. D. IRVING: Monograph V., U. S. G. S., Copper-bearing Rocks of the Lake Superior Region, pp. 99-100, Pl. XIII., Fig. 13-14, 1883.

G. H. WILLIAMS: Neues Jahrbuch für Min., etc. B. B. II. 1882, S. 607, Pl. XII., Fig. 3. The Peridotites of the Courtland series. Am. Jour. Sc., Vol. XXX., p. 30, Vol. XXXIII., p. 139.

E. HAWORTH: A Contribution to the Archæan Geology of Missouri, Am. Geol., 1888, Vol. I., p. 368, Figs. 1 and 2, Pl. I.

WHITMAN CROSS: On some Eruptive Rocks from Custer Co., Colorado. Proc. Col. Sc. Soc., Vol. II., 1888, pp. 232, 242.

On a series of peculiar schists near Salida, Col. Proc. Col. Sc. Soc., Jan., 1893, p. 8.

J. P. IDINGS: The Eruptive Rocks of Electric Peak and Sepulchre Mountain, Y. N. P. 12th Ann. Rep. U. S. G. S., pp. 589, 646.

WALDEMAR LINDGREN: A Sodalite Syenite and other Rocks from Montana. Am. Jour. Sc. (3), Vol. XLV., April, 1893, p. 287.

J. S. DILLER: Mica-peridotite from Kentucky. Am. Jour. Sc. (3), Vol. XLIV., Oct., 1892, p. 287.

J. J. HARRIS TEALL: British Petrography, 1888, p. 337.

ALFRED HARKER: Bala Volcanic Series of Rocks, pp. 23, 53, 54.

A. C. BRÖGGER: Der Mineralien der Syenitpegmatitgänge der süd-norwegischen Augit- und Nephelinsyenit. Groth's Zeitseh. für Krys., etc., Vol. XLV., p. 546.

OTTO NORDENSKJÖLD: Zür Kenntniss der s. g. Hälleflinta des Nördostlichen Smalands. Bull. Geo. Ins. Upsala, No. 1, Vol. I., 1893, p. 232.

<sup>2</sup>A section of this felsite, loaned by Professor Pirsson, possesses an interesting and striking resemblance to the South Mountain acid volcanics, and indicates the southward persistence of this rock type.

<sup>3</sup>Thin sections of these felsites were kindly loaned by Mr. Diller. They have many microscopic features in common with the South Mountain rocks, and like them were first referred to a sedimentary origin. J. S. DILLER: Felsites and their associated Rocks north of Boston. Proc. Bos. Soc. Nat. His., Vol. XX., Jan. 21, 1880. Bull. Mus. Comp. Zoöl., Harvard College, whole series Vol. XII., Geol. series Vol. 1.

affect the orientation of the cement. Where the rock is coarser grained, as is the case in some of the basic volcanics, the character of the cement can be directly tested and the material proved to be quartz.

While in some cases this structure is undoubtedly of primary character, as Professor Iddings considers it to be in many porphyrites, in a large class of rocks its secondary origin seems equally plain. Dr. Irving, who very early described this structure in the acid lava flows of the Keweenaw series, thus speaks of its origin.<sup>1</sup> "Whether this secondary quartz may ever be rather a result of devitrification than a truly secondary or alteration-product I have no means of deciding, though it is certainly the latter often, and I should suppose always. It surely can have no connection with the original solidification of the rock." Observations made on the South Mountain rocks likewise point to a secondary origin for these quartz areas. As the origin of the structure is of importance in its bearing on the question of the primary or secondary character of the crystalline ground-mass, these observations will be briefly mentioned. In a specimen of basic lava from the railroad tunnel near Monterey the outline of lath-shaped feldspars forming an ophitic structure, which is undoubtedly original, is completely preserved. None of the original constituents of the rock remain, however, unless some of the titaniferous iron oxide is original. The rock consists entirely of quartz, epidote, magnetite (or ilmenite), and leucoxene. The quartz acts as a cement for the other minerals, forming irregular interlocking areas which are quite similar to the micropoikilitic areas of the acid rocks and which produce in polarized light the familiar patchy effects. Fine cracks traversing the rock, and parting the ferro-magnesian phenocrysts (now represented by epidote) are plainly prior to the quartz areas in which they become invisible. There can be no question as to the secondary character of the micropoikilitic structure in this case.

In the acid rocks the quartz areas are frequently more or less oval and outlined by a microfluidal arrangement of globulites,

<sup>1</sup> Opus cit., p. 100.

longulites and trichites of iron oxide. Zirkel figures and describes a similar appearance in the rhyolites of the 40th parallel.<sup>1</sup> He speaks of faint granular lines "which by their fluidal running form a net with a multitude of meshes of oval shape." The meshes are filled by one of two types of crystallization, the micro-felsitic or the spherulitic. The lines suggested to Zirkel perlitic parting. In the ancient lavas of South Mountain the meshes are filled by the micropoikilitic areas or by spherulitic crystallization or by intermediate stages of alteration, that is, spherulites more or less broken up into micropoikilitic areas. In the trichitic spherulites of the modern rhyolites<sup>2</sup> there is an appearance similar to the micropoikilitic mottling, caused by the breaking up of the radiating spherulitic fibers into irregular areas which extinguish differently; just such an intermediate stage between the spherulitic and a completely micropoikilitic crystallization as has been noted in the ancient volcanics. These observations suggest that the micropoikilitic structure represents recrystallized spherulitic growths when it is not the direct results of infiltration and devitrification. In many cases, the crystallization has undoubtedly never been spherulitic, if however, the micropoikilitic structure has been shown to be subsequent to spherulitic crystallization, that is, to the consolidation of the rock in numerous instances in the acid volcanics, selected from widely separated localities in the South Mountain, the presumption favors the secondary origin of the micropoikilitic structure wherever present in these rocks.

*Spherulitic structure.*—Two sorts of spherulitic crystallization are present in these rocks. They differ in no essential respect but are unlike in appearance. The most numerous spherulites are also the simplest and smallest. They are colorless microscopic spheres, scarcely or not at all perceptible in ordinary light but showing the usual distinct dark cross between nicols. Spheru-

<sup>1</sup> Vol. VI., Geo. Exp. of the 40th parallel, Fig. 1, Pl. VI., Fig. 1, Pl. VIII.

<sup>2</sup> Sections of material from the Rosita Hills, Colorado, and of the Obsidian Cliff, Y. N. P., were kindly loaned the writer for comparative study by Dr. Cross and Professor Iddings.

lites, in every respect similar, have been described and figured by Professor Iddings from the Yellowstone Park rhyolites.<sup>1</sup> While it is not impossible that some of the colorless spherulites are secondary, there is pretty good evidence that many, if not all of them, are primary. These spherulites are embedded in a base which suggests in every way a former glassy condition. In ordinary light there is no appearance of crystallization except the porphyritical. Traversing the groundmass are cracks which occasionally cut directly through a spherulite. Between crossed nicols the field breaks up into a holocrystalline quartz-feldspar mosaic in which the cracks are lost. It seems fair to conclude that the spherulitic crystallization was prior to the cracking, that the granular crystallization is subsequent, and that the cracking took place in an already solidified glass. In these facts we again find obvious indications of a secondary crystallization. In this case the process seems to have been one of devitrification. The other class of spherulites corresponds to those figured by Professor Iddings in Plate XVII.<sup>2</sup> They are much larger than those which have just been described; the smallest being easily discernible by the unaided eye, and the largest about the size of a butternut. Hence they become a conspicuous feature of the rock as exhibited in the field. They are rarely altogether absent, and in some localities are crowded so close together as to constitute the major part of the rock mass. When without regularity of arrangement, and when brought out in relief by weathering, these spherulites give to the rock a superficial resemblance to a conglomerate composed of rounded pebbles of uniform size and shape. The rich greys, blues, purple and red of the spherulites and matrix render this a conspicuous rock.

Spherulites become an even more striking feature of these rocks when arranged in layers such as have been described in the modern rhyolites of the Yellowstone National Park.<sup>3</sup> On a face of the rock normal to the layers, they appear as long

<sup>1</sup> Opus cit., Pl. XVII., p. 276.

<sup>2</sup> Opus cit. p. 277.

<sup>3</sup> IDDINGS: opus cit. p. 276, Pl. XVIII.

parallel bands simulating lines of bedding. Sometimes these bands are 4 m. m. wide, at a nearly uniform distance apart and of an indefinite length. In other cases they are very narrow, dwindling into mere lines and dying out, to be replaced immediately by other lenticular bands. The rock cleaves readily parallel to the planes of these bands, which have become planes of weakness and solution, and the spherulites are entirely replaced by secondary silica. This fact, imparting to the bands an opaque white color, render them the more conspicuous in contrast with the blues or reds of the rock surface.

The spherulites which remain unaltered show in the thin section clear cut, circular, semicircular, and fan-shaped outlines, and are colored purple or red by finely disseminated particles arranged either radially or concentrically in threefold zones. Feldspar phenocrysts often occupy the center of the radial growth. These well preserved spherulites are associated with a groundmass which preserves the characteristics of a glass in great perfection, and which, in ordinary light, could readily be mistaken for a fresh glassy lava. It bears the closest resemblance to the base of some of the Colorado rhyolites. Delicate perlitic parting, which because of its delicacy is usually obliterated, is here preserved in wonderful detail. The presence of innumerable globulites accentuates the perlitic and rhyolitic structures. With crossed nicols the aspect of the groundmass completely alters. All glassy structures disappear, to be replaced by granular quartz and feldspar.

It is impossible by any description to carry the definiteness of conviction as to the original glassy nature of the groundmass which the character of such rock-sections justifies. To one who has studied them in both ordinary and polarized light there can be no question as to the secondary character of the holocrystalline groundmass. One cannot escape the conviction that the rock originally consolidated as a spherulitic perlite, and has become holocrystalline by a process of devitrification.

Associated with a groundmass, whose early glassy condition is not so strongly marked, are the altered spherulites. Their spherical



shape in the hand specimen and their sharply defined outline in the thin section in ordinary light alone testify to their former presence. With crossed nicols these boundaries become inconspicuous, and the field of the microscope shows only a uniform quartz-feldspar mosaic. The crystallization within the spherulitic boundary is sometimes finer grained than that of the groundmass, or the micropoikilitic structure is present in the former when absent from the latter, otherwise the spherulite is in no way distinguished from the groundmass. In the case of the chain spherulites the alteration is complete and universal. There is, in ordinary light, an impressive similarity with the fresh chain spherulites of the Yellowstone Obsidian. The same irregularly scalloped outline, the same central chain of clear spherules. With crossed nicols the close similarity vanishes, for in the ancient rocks the radial growth has utterly disappeared. The clear spherules are composed of finely granular quartz while the sinuous border is not to be distinguished from the quartz-feldspar groundmass.

*Axiolitic structure.*—Closely related genetically to the chain spherulites, but unlike them in being linearly radial rather than centrally, is the axiolitic formation.<sup>1</sup> These have been described in rhyolites and occur somewhat sparingly in their ancient prototypes of the South Mountain.

*Rhyolitic structure.*—The sections in which the axiolites were observed possess a holocrystalline character, but exhibit in ordinary light flow and vesicular structures, together with stringers and shreds and curved patches of a brownish red color forming what has been called a rhyolitic structure. This latter structure, which has been figured and described by Rutley,<sup>2</sup> Nordenskjöld,<sup>3</sup> and Vallée-Poussin,<sup>4</sup> and on a macroscopic

<sup>1</sup> ZIRKEL : opus cit. p. 167.

<sup>2</sup> RUTLEY : On the Microscopic Structure of Devitrified Rocks from Beddgelert and Snowden. Q. J. G. S., Vol. XXXVII., 1881, p. 406, Fig. 1-2.

<sup>3</sup> NORDENSKJÖLD : opus cit., p. 5.

<sup>4</sup> VALLÉE-POUSSIN : Les Anciennes Rhyolites dites Eurites de Grand-Manil. Bull. de L'Acad. Roy. de Belgique, 3d series, Tome 10, 1885, p. 271.

scale by Irving,<sup>1</sup> is essentially nothing else than a special phase of the fluidal structure, a phase peculiar to flowage in lava consolidating with extreme rapidity, that is, in an acid glass. The granular crystallization has developed with entire disregard to these curved patches, shreds and stringers.

*Lithophysal structure.*—Often the macroscopic features of the South Mountain acid volcanics disclose their original character more convincingly than does the microscope. Lithophysæ are one of the structures which are best revealed in the hand-specimen, where they are brought out in delicate relief by weathering. The rose-pink petals of the lithophysæ in a paler pink base produce quite as beautiful specimens of this glassy structure as any rhyolite shows. The *micro-pegmatitic structure* shows itself in microscopic pegmatoid groups of phenocrysts such as are found in the Yellowstone rhyolites.<sup>2</sup>

*Perlitic parting.*—That this structure is occasionally present in the South Mountain rocks in great perfection has already been noted. While its presence is a most reliable test of the former character of the rock, its absence furnishes no evidence against the previous glassy condition of the rock, both because many recent rhyolites show no trace of that structure and because it is most readily effaced by devitrification.

*Amygdaloidal structure.*—In some localities the acid volcanics are conspicuously amygdaloidal. The bright green amygdules of epidote in a pale pink matrix render this rock strikingly handsome. In a few instances<sup>3</sup> the vesicles, which, as seen under the microscope, are bordered by a broad rim, like the ground-mass in crystallization, but are separated from it by a clear zone of silica and are darkened by an abundance of black iron oxide, bear on the inner edge of this border spherulitic growths. These are surrounded by a clear zone of silica while the center of the vesicle is filled either with an opaque black

<sup>1</sup> IRVING: opus cit., pp. 312-313, Fig. 22.

<sup>2</sup> IDDINGS: opus cit., p. 275, Pl. XV., Fig. 5.

<sup>3</sup> In specimens from Raccoon Creek at the east base of Piney Mountain, south of Caledonia Furnace.

oxide or with granular quartz. Crossed nicols show that the spherulites are oriented optically with the surrounding silica, and that the preservation of the radiate structure is due to the arrangement of impurities. The appearance of these vesicles is very like those figured by Professor Cole,<sup>1</sup> who explains their formation by a dual mode of growth—a growth from the groundmass outward converging toward a center, as well as from the center. Whatever may be the facts with reference to the Roche Rosse Obsidians, it is not necessary to call into play an abnormal method of crystallization to explain the phenomena observed in the South Mountain rocks. The spherulites projecting into the vesicles, with their bases sunk into its wall, were recognized by Professor Iddings, who kindly examined the sections, as tridymite spherulites, such as form on the walls of vesicular cavities in all modern lavas.

*Taxitic structure.*—Still another structure which the South Mountain rocks possess in common with rhyolites is what has been called the taxitic. This consists in the intimate mingling of two portions of the magma, which, from some cause (liquefaction), are slightly differentiated. The iron constituent, which evidently separated out in the original glass, has been still further crowded into bands and curved lines by the secondary crystallization. The result is the production in some cases of an irregular mottling: *ataxites*; and in other cases of a more or less complex network of interlacing bands following lines of flow: *eutaxites*. This mottling and banding is rendered the more striking by a marked contrast in color. The body of the rock is light gray or pink, and the lines dark blue, gray or red, according as the iron is more or less oxidized. When the iron constituent is arranged in oval or spherical outlines, denoting the former presence of spherulites, the rock may properly be termed a *spherotaxite*.<sup>2</sup>

<sup>1</sup>GRENVILLE A. J. COLE and GERARD W. BUTLER: on the Lithophysæ in the Obsidian of the Roche Rosse, Lipari. Q. J. G. S., Vol. XLVIII., p. 438.

<sup>2</sup>Note sur les Taxites et sur les Roches clastique Volcanique. Bul. de l' Soc. Belge, d'Geo. et Tome V., 1893.

*Trichitic structure.*—The universal presence of globulites, trichites and microlites of black and red iron oxide, in flow bands, or indifferently distributed, or in concentric zones around spherulites and vesicles is worthy of mention as a further point of resemblance to the modern rhyolite. Such trichites in similar rocks have been described by various petrographers.<sup>1</sup> Such, in brief, is the character of the evidence for the secondary nature of some of the holocrystalline groundmass of the acid volcanics of the South Mountain. It is not easy to present the proof so that it shall carry the weight which justly belongs to it. Very much depends upon effects which it is impossible to reproduce by description, but which carry conviction to the student of these rocks. The contrasting appearance of the sections in ordinary and polarized light cannot be adequately reproduced. The disappearance under crossed nicols of rhyolitic, perlitic, spherulitic, and fluxion structures, so clearly indicated in ordinary light, and their replacement by a homogeneous holocrystalline mosaic is one of the strongest evidences of the secondary character of the crystallization. Nor are there lacking instances where the subsequent nature of the crystallization is in other ways distinctly proven, as in the replacement of radial crystallization by the granular aggregate of quartz and feldspar, which is homogeneous with a granular groundmass, as well as in the character of the micropoikilitic structure. One or more of the structures which have been described are invariably present in the acid volcanics of certain localities. The occurrences, where their structures are absent, show a genetic relationship in the field to typical representatives of the modern rhyolite.

The writer considers that the acid lava flows in South Mountain were, at the time of their consolidation, quite comparable to similar flows as they now appear in the Yellowstone National Park. Certain portions of the flow, as in the case of

<sup>1</sup> S. ALLPORT: On certain ancient divitrified Pitchstones and Perlites from the lower Silurian District of Shropshire. Q. J. G. S., Vol. XXXIII., p. 449.

O. NORDENSKJÖLD: opus cit.

R. D. IRVING: opus cit. p. 312.

the Obsidian Cliff, were completely vitreous save for spherulitic and lithophysal crystallization. In other localities the lava was lithoidal, and in the central portion of thick flows holocrystalline. In this way three types of acid volcanics would be developed—rhyolites, lithoidal rhyolites, and quartz porphyries. Every gradation between these types would accompany them. Thus, while there are certain areas in the South Mountain, notably the Bigham Copper Mine and Racoon Creek localities, which exhibit typical ancient rhyolites, other regions display genuine quartz-porphyries. While in the latter rocks, which constitute a large part of the acid volcanics, the groundmass may have been, and probably was, originally holocrystalline, as in some modern lavas; in the case of the former rocks, it is supposed that the groundmass was, at the time of consolidation, wholly or partly glassy. The secondary character of some of the holocrystalline groundmass once conceded, and the indications of an original glassy base recognized, it is easy to suppose that the former was developed from the latter by a process of *devitrification*.

That the process of crystallization does not necessarily cease with the solidification of a rock is well known. That the crystallizing forces are active in a glass as well as in a molten magma has been proven by experiment.<sup>1</sup> This action is exceedingly sluggish, and requires, unless accelerated by heat and moisture, an immense amount of time. Devitrification has been considered the result only of dynamic action.<sup>2</sup> While dynamic action undoubtedly accelerates the process of devitrification, if it does not initiate it, devitrification may also take place independently of dynamic action, as was the case in the famous example of the old cathedral window-glass<sup>3</sup> and the ancient devitrified glass from Nineveh investigated by Sir David Brewster.<sup>4</sup> The nature

<sup>1</sup> DAUBRÉE : Géologie Expérimentale, 1879, p. 158.

<sup>2</sup> VALLÉE-POUSSIN : Les Eurites quartzéuses (rhyolites anciennes) de Nivelles et des Environs. Bull. Acad. Roy. Sc. Lett. et des Beaux Arts de Belg. 56 annue, 3d series, Tome 13, No. 5, 1887, pp. 521-522.

<sup>3</sup> Brit. Assoc. Rep., 1840.

<sup>4</sup> Trans. Roy. Soc. Edin., Vols. XXXII., XXXIII.

of the process is in no way different from the process of crystallization in a fluid magma, save in the rapidity of the action, and is of both a physical and chemical character. It is not the purpose of this paper to discuss the other evidences of metamorphism in the South Mountain rocks. There is ample proof that both dynamic and statical metamorphism were wide spread. While the former would, by shearing, obliterate the original structures of a glassy rock and produce a slate, the latter might be an important initiatory and accelerating factor in the process of devitrification of the glassy rocks.

*Nomenclature.*—The character of the acid rocks has been briefly presented, and there remains to be considered a name or names which shall be descriptive of them. While the possibility of devitrification can hardly be doubted, the fact that a finely crystalline aggregate of quartz and feldspar may also be the direct product of consolidation from a molten magma is equally recognized by the writer, and to the acid rocks possessing such a groundmass the name quartz-porphyry is given. It is by no means always possible to distinguish between a primary and secondary crystalline groundmass, hence no attempt is made to draw a sharp line between the quartz-porphyries and the devitrified rhyolites.

The typical ancient originally glassy acid volcanic should be distinguished in some way by the name from the typical ancient originally holocrystalline acid volcanic. Is there any name now in use which does this? A great variety of terms has been applied to the acid type of the older volcanic rocks. Under the general group of quartz-porphyries, Rosenbusch classifies them as *microgranites*, with a microgranitic groundmass, *granophyres* with a micropegmatic groundmass, *felsophyres*, with a microfelsitic base, and *vitrophyres* (including pitchstones and pitchstone porphyries), with a vitreous base. Foqué and Lévy use *microgranitite*, *micropegmatite* and *porphyre petrosiliceux* as corresponding terms. By British petrographers these acid rocks have been termed hornstones, claystones, and claystone porphyries, felsites, quartz-felsites, and felsites porphyries, agreeing in this respect

with the older German usage, when they have not followed Rosenbusch. In America both German and English usage has been followed with more or less confusing results. In the nomenclature of the South Mountain rocks an effort has been made to avoid such confusion and to use such a term or terms as shall accurately describe them and all similar rocks. No one of the terms mentioned succeed in doing this. Although, perhaps, most nearly like the felsophyres, these South Mountain rocks cannot be included under that term since they now possess a holocrystalline groundmass.

In so much as many of the English felsites have been shown by Rutley, Allport, Cole, and Bonney to be devitrified obsidians and pitchstones, and thus, like these American rocks, the representatives of the glassy lavas of pre-Tertiary times, these pre-Cambrian lavas of the South Mountain might with some propriety be termed *felsites*. Felsites, however, though useful as a field name may well be objected to as an inaccurate petrographical term. It was originally used to describe an acid base, unresolvable to the naked eye, and at first supposed to be a single mineral.<sup>2</sup> With the introduction of the microscope this macro "felsitic" base was resolved into the microgranitic, micro-pegmatitic, and microfelsitic groundmass, the point of ignorance being shifted from the felsitic base, macroscopically unresolvable to the microfelsitic base, which is microscopically unresolvable. On the continent felsite has been practically replaced by these terms. British and American petrographers have retained it as a field name for rocks formed of this macroscopically unresolvable base without phenocrysts or with inconspicuous phenocrysts. The South Mountain rocks are both without phenocrysts, with inconspicuous phenocrysts, and with abundant and conspicuous phenocrysts. As this irregular distribution of the porphyritic crystals may characterize a single lava flow, it does not seem a sufficient ground for a separation of rock types.

<sup>2</sup> GERHARD: Beiträge zur Geschichte des Weissteins des Felsit und anderer verwandten Arten" Abhandl. der k. Akad. der Wissensch. zu Berlin, 1814-1815, s. 18-26. Naumann Lehrbuch der Geognosie Band 1, 2d ed. 1858, s. 597.

It is very generally recognized that structural features are not conditioned by the geological age of rocks, but are, on the other hand, a function of the conditions of consolidation. That the conditions attending the consolidation of surface flows in pre-Tertiary times do not differ from those attending the consolidation of similar flows in post-Tertiary times has been illustrated by a wide survey of pre-Tertiary and Tertiary rocks on the part of Allport, Judd, Teall and others<sup>1</sup>. With this recognition has come the growing conviction among petrographers that mere age should be eliminated as a factor in rock nomenclature.<sup>2</sup> While this is true, it is felt, on the other hand, that there should be some recognition in the rock name of the alteration which the rock has undergone subsequent to its solidification. If, at the time of its solidification, the rock presented the features of a rhyolite, as it is believed much of the South Mountain acid lava did, but since that time has become holocrystalline, both these facts, its original character and its present alteration, should be recognized in the name.

Such a result might be secured by the retention of such well established names as rhyolite, obsidian, trachyte, etc., preceded by a prefix which shall have such a designation as to indicate the altered character of the rock. The prepositions *meta*, *epi* and *apo*, as prefixes, all indicate some sort of an alteration. Their exact force has been thus defined by Professor Gildersleeve: *meta* indicates change of any sort, the nature of the change not specified. This accords with the use of the prefix by Dana in such terms as "metadiorite" and "metadiabase." These terms have been recently revived to designate rocks "now similar in mineralogical

<sup>1</sup>ALLPORT: Address of the Pres. of the Geo. Sec. of the British A. A. A. S., 1873, and many other writings by the same author.

JUDD: On the Gabbros, Dolerites and Basalts of Tertiary Age in Scotland and Ireland. Q. J. G. S., Vol. XLII., 1886, pp.49-97.

TEALL: British Petrography, pp. 64-69.

<sup>2</sup>Reyer, Tietze, Reiser, Reusch (H. H.), and Suess support the statement that age is not a just ground of distinction between eruptive rocks, and Rosenbusch considers that in no very distant future the separation of effusive rocks into an older and a younger series will prove untenable.



composition and structure to certain igneous rocks, but derived by metamorphism from something else."<sup>1</sup> *Epi* signifies the production of one mineral *out of* and *upon* another. This prefix has not been much used. We find it in such terms as epidiorite, epigenetic hornblende and epistilbite. *Apo* may properly be used to indicate the derivation of one rock from another by some specific alteration.

If, therefore, we decide to employ this prefix to indicate the specific alteration known as devitrification (*Entglasung*) we may obtain, by compounding it with the name of the corresponding glassy rocks, a set of useful and thoroughly descriptive terms, like *aporhyolite*, *apoperlite*, *apobsidian*, etc., as to whose exact meaning there can be no doubt. In accordance with this usage it is proposed to call all the acid volcanic rocks, whose structures prove them to have once been glassy, *aporhyolites*. While those which have consolidated at a sufficient depth to secure a holocrystalline groundmass should be termed *quartz-porphyrtes*, whether ancient or modern lavas. The writer realizes that the introduction of a new name into petrographical nomenclature is to be deplored unless it can be shown that the name is formulated in accordance with certain well defined principles. A good rock name should express composition, original structure, and, as far as possible, the process of alteration, if any, that the rock has undergone. It is thought that *aporhyolite* and the suggested series of similarly formed terms meet these requirements. They are, therefore, adopted as preferable to any in present use.

Paleozoic and pre-Paleozoic acid volcanics have long been studied on the Continent, Although their variation from the modern type of acid volcanic, rather than their resemblance to that type, has for the most part been emphasized by German and French petrographers, there have not been wanting able advocates of devitrification and of an original glassy base for the ancient lavas. R. Ludwig (1861), and Vogelsang<sup>2</sup> (1867)

<sup>1</sup> WHITMAN CROSS: On a Series of Peculiar Schists near Salida, Colorado. Proc. Col. Sc. Soc., 1893, p. 6.

<sup>2</sup> Philos. d. Geologie, 144, 153, 194.

incline to the opinion that the groundmass of certain quartz-porphyrries is the result of the devitrification of a glassy lava. The late Dr. K. A. Lossen<sup>1</sup> (1869), on comparing the spherulitic porphyries of the Harz Mountains with the obsidians of Lipari, Mexico and Java, found the resemblance sufficiently striking to lead him to declare that "the porphyry groundmass was originally crystallized as glass, and became cryptocrystalline through molecular rearrangement." Later, Kalkowsky<sup>2</sup> (1874) suggests devitrification through the chemical activity of water, as the process by which the microfelsitic base of certain pitchstones and felsites was developed, and still later H. Otto Lang<sup>3</sup> (1877) described a macroscopically unindividualized base which is similar microscopically to the devitrified base described by Kalkowsky. Sauer (1889) considers the Dobritz porphyries as the final alteration product of a pitchstone. C. Vogel comes to the same conclusion as to the Umstädt porphyries in Hessen.

More recently Klockmann<sup>4</sup> (1890) describes the replacement of the spherulitic crystallization in quartz-porphyrries, through secondary processes, by a fine grained aggregate of quartz and feldspar. Osann<sup>5</sup> (1891) describes incipient devitrification in perlite and other glassy rocks from Cabo de Gata. Finally, Link (1892) considers that it is not impossible that the fine grained groundmass of some rocks from America that are closely related to mica-syenite-porphyrries, was once glassy or at least partially glassy. Many no less capable observers still hold to an original difference between ancient and recent acid volcanics, and the possibility of devitrification and original similarity is yet an open question in Germany.

<sup>1</sup>Beiträge zur Petrographie der Plutonischen Gesteine Abh. der Berliner Akad. 1869, p. 85.

<sup>2</sup>Mikroskopische Untersuchungen von Felsiten und Pechsteinen Sachsens T. M. P. M., 1874, pp. 31-58.

<sup>3</sup>Heinr. OTTO LANG: Grundriss der Gesteinskunde, 1877, p. 43.

<sup>4</sup>F. KLOCKMANN: Die Porphyre der Geol. d. s.g. Magdeburger unferandes m. besonderes Berücksichtigung d. auftretenden Eruptivgesteine Jahrbuch k. p. Geo. Land. u. Bergakad. zu Berlin, 1890, vol. XI.

<sup>5</sup>Z. Geol. Ges. 691, 716.

In France, La Croix<sup>1</sup> describes andesites from Martinique in which the glass has altered into quartz spherulites and a granular quartz aggregate. It is interesting to note that many of the hälleflinta of Sweden, which, like the South Mountain volcanics, were once described as sedimentary, are proving to be acid volcanics preserving the features of their modern equivalents. Quite recently, glassy and rhyolitic structures in these rocks have been observed and described by Otto Nordenskjöld.<sup>2</sup> In Belgium Vallée-Poussin seems to be the only writer who has brought out the resemblance between the eurites of that country and modern rhyolites. He describes at some length structures similar to those possessed by the aporhyolites of South Mountain. A vacillating state of mind as to the matter of nomenclature is indicated in the titles of his successive papers.<sup>3</sup>

In England the rhyolitic character of the ancient acid volcanics has been recognized and emphasized, and the idea of devitrification is widely accepted. Allport, Cole, Bonney, Rutley and Harker have accomplished most valuable work along this line. Dr. Wadsworth<sup>4</sup> was the first American petrographer to advocate the abandonment of age as a factor in rock classification; while at the same time he recognized devitrification as the process which has been forming felsites out of rhyolites. What he says is of interest in its anticipation of ideas now more generally accepted. "This devitrification gives rise in the older and more altered rhyolites to the feldspar, quartz and microfelsitic

<sup>1</sup> Comptes rendus, CXI., p. 71.

<sup>2</sup> Opus cit.

<sup>3</sup> Les Anciennes Rhyolites dites Eurites de Grand-Manil. Bull. Acad. R. de Belg., 3d series, Tome 10, 1885, pp. 253-315.

Les Eurites quartzzeuses (rhyolite anciennes) de Nivelles et des Environs. Bull. Acad. R. des Sc. et des Beaux-Arts de Belg. 56 annue, 3d series, Tome 13, No. 5, 1887.

<sup>4</sup> M. E. WADSWORTH: Notes on the Minerology and Petrography of Boston and vicinity. Proc. Boston Soc. Nat. His., vol. XIX., May, 1877, p. 236.

On the Classification of Rocks. Bull. Mus. Comp. Zoöl., Harvard College, vol. V., No. 13, June, 1879, p. 277.

(so-called) base that has so puzzled lithologists in the study of the felsites. The rhyolites of all volcanic rocks preëminently show lamination produced by flowing, a fact which is doubtless due to their being so siliceous. This structure and their devitrification enables us to trace a direct connection between the rhyolites and felsites, which are simply the older and more altered rhyolites. . . . One of the best illustrations of this is to be found on Marblehead Neck, Mass., where at least two distinct flows of felsite occur, one cutting the other. They show the fluidal structure so characteristic of rhyolites,—a character that has been mistaken for lines of sedimentation by geologists. While the enclosed crystals of orthoclase have been taken for pebbles. . . . While to the naked eye and under the microscope this rock shows the fluidal structure of a rhyolite, in p. 1. it is seen that the base has been completely devitrified, a process that is carried to a great extent in many known modern rhyolites.” No other American petrographer has so distinctly advocated the identity of felsites and ancient rhyolites in spite of the fact that many of our felsites illustrate it as unmistakably as do the English felsites. Dr. Irving<sup>1</sup> in his description of the Beaver Bay group of the Keweenaw series repeatedly calls attention to the resemblance between the ancient felsites and quartz-porphyrines and the modern rhyolites, although he does not express an opinion as to their equivalence. The statement “that the degree of crystallization developed in igneous rocks is mainly dependent upon the conditions of heat and pressure under which the mass has cooled and is independent of geological time” made by Messrs. Hague and Iddings<sup>2</sup> expresses essentially the position of American petrographers on this question.

Apparently in none of the felsites elsewhere described have the varied structures of the modern rhyolite been more perfectly and conspicuously preserved than in the aporhyolites of the South Mountain.

<sup>1</sup> *Opus cit.*, pp. 312, 313, note 5, p. 436.

<sup>2</sup> On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, with Notes on the Geology of the District, Bul. 17 U. S. G. S. 1885, p. 40.

The subject discussed in this paper forms a part of a thesis, on South Mountain, presented at the Johns Hopkins University. The petrographical study was conducted in the petrographical laboratory of that institution, under the immediate supervision of Professor G. H. Williams, to whose valuable suggestions and stimulating interest the writer is in every way indebted.

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